Direct Measurement of Lifetime of Heavy Hypernuclei at CEBAF

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Physics Motivations

- Study hadronic weak interactions by the unique $\Lambda N \rightarrow NN$ (nonmesonic) decay in the nuclear medium after formation of Λ-hypernuclei
- Examine the role and limit of the empirical rule of $\Delta I=1/2$ rule in the hadronic weak interaction models
- Provide crucial information on the short range nature of the ΛN interaction

Unresolved Issues

- The nature of $\Delta I=1/2$ rule is unknown
- Chiral effective field theories in SU(3) realm with $\Delta I=1/2$ failed to describe hadronic decay rate in the nuclear mudium
- Is this rule violated in $\Lambda N \rightarrow NN$ thus weak model needs $\Delta I=3/2$ terms and how much?
- Γ_n/Γ_p is directly related to the violation level of $\Delta I=1/2$ rule:

$\Gamma_n/\Gamma_p \leq 0.3$	$\Delta I=1/2$ rule hold
$\Gamma_n/\Gamma_p > 0.3$	Need $\Delta I=3/2$ terms by unknown natures

Measurements for Light Hypernuclei (KEK)

- $\leq$10% errors in τ_Λ but insensitive to Γ_n/Γ_p
- Asymptotic τ_Λ (~200ps) hints small Γ_n/Γ_p thus not strong violation of $\Delta I=1/2$ rule
- Direct measurement of Γ_n and Γ_p is crucial but experimental errors were too large:

  $$\delta(\Gamma_n/\Gamma_p) \sim 100\%$$

  although Γ_n/Γ_p is given about 0.6 – 1.0
- Theory needs $\delta(\Gamma_n/\Gamma_p) \leq 20\%$ accuracy

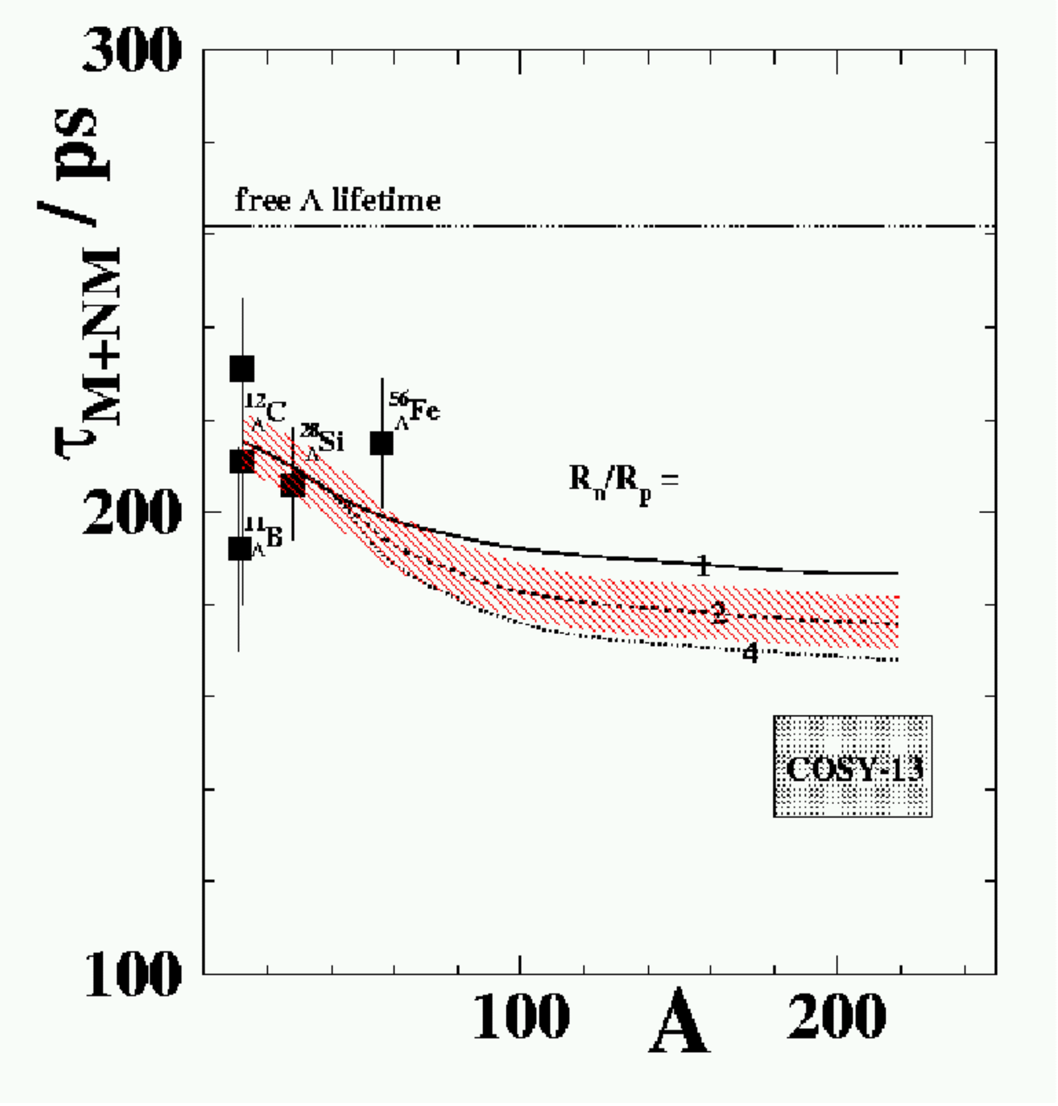
Measurements for Heavy Hypernuclei (COSY)

- Impossible to directly measure of Γ_n and Γ_p
- Reasonable sensitivity of Γ_n/Γ_p to τ_Λ
- COSY measurement was indirect
  - Recoil distance $\Rightarrow$ Lifetime
  - Model dependent
  - Large systematic error ($\geq$15%)
  - Stangeness and hypernuclear production were not positively identified
- Result shows conflict by hinting high Γ_n/Γ_p

Illustration

From COSY-13 results:

1. Strong violation of $\Delta I=1/2$ rule?
2. Error still too large.
3. Hypernuclei?



W. Cassing et al., nucl-ex/0108027 (2001), submitted for publication on Acta Physica Polonica B.

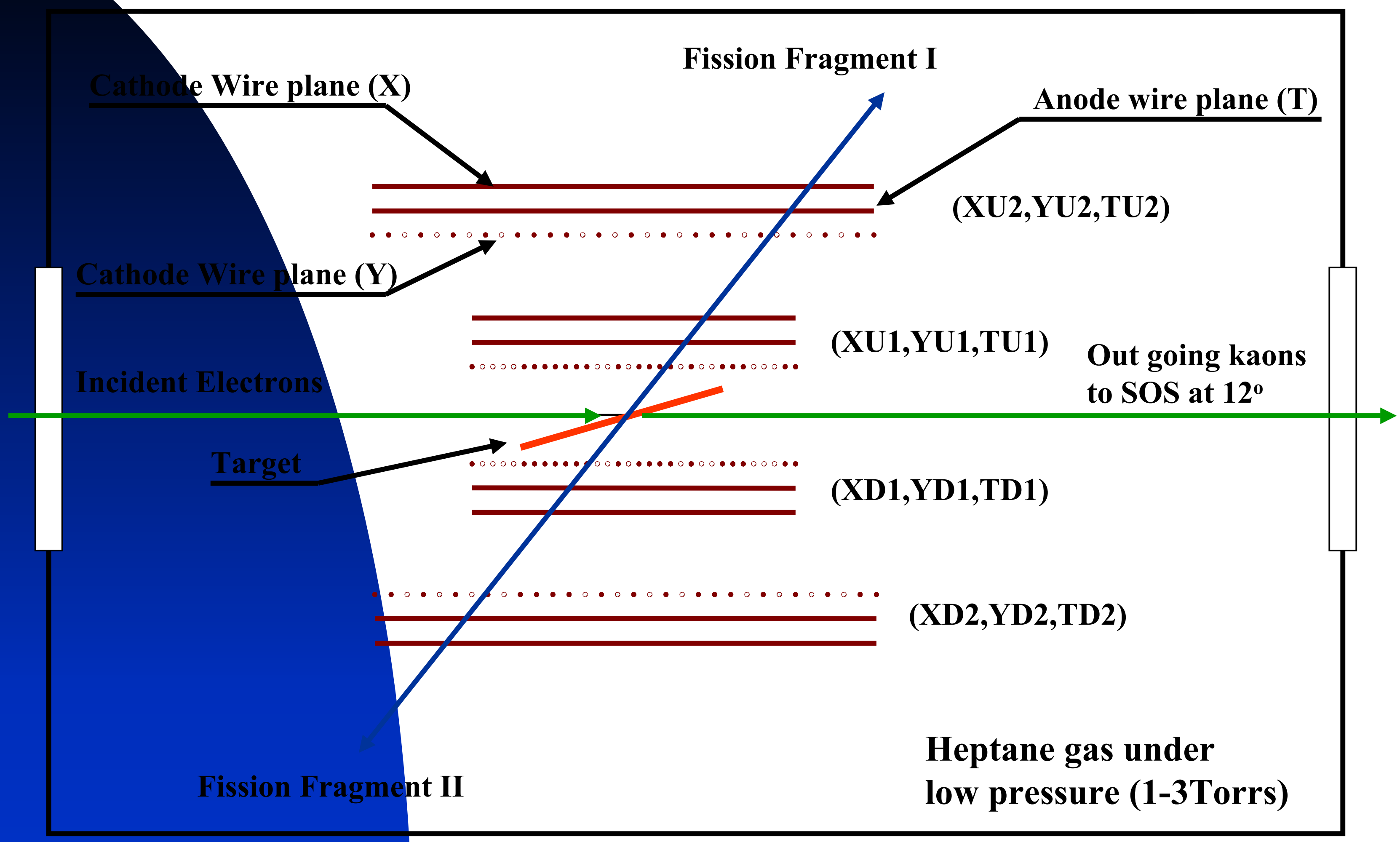
Thrust of JLAB Experiment

- Direct Lifetime measurement from decay time spectrum of Bi-Λ–hypernuclei (A=208)
- Gate positively on strangeness and hypernuclear production
- Minimized systematic error
- Maximized overall precision ($\leq$5%)
- Examine the A dependence by comparing KEK and COSY results
- Examine the range of Γ_n/Γ_p, although not directly measured

Technique of JLAB Experiment

- Unique beam structure (1.67ps width and 2ns separation)
- Good kaon detection (SOS) and production time reconstruction to directly point to time zero and positive identification of strangeness and hypernuclear production
- Excellent identification of $\Lambda N \rightarrow NN$ decay from fission
- 2ns gate for kaon and fission fragment coincidence selects hypernuclear production and decay only
- Very low accidentals
- Excellent fission fragment detection by Low pressure MWPC ($\sigma_t \approx 130$ps and $\sigma_x \approx 150\mu$m per chamber) and sensitive only to high Z fragments
- Precise prompt time spectrum measurement from proton and FF coincidence that will be naturally contented in the raw data taking

Schematic View of Experiment



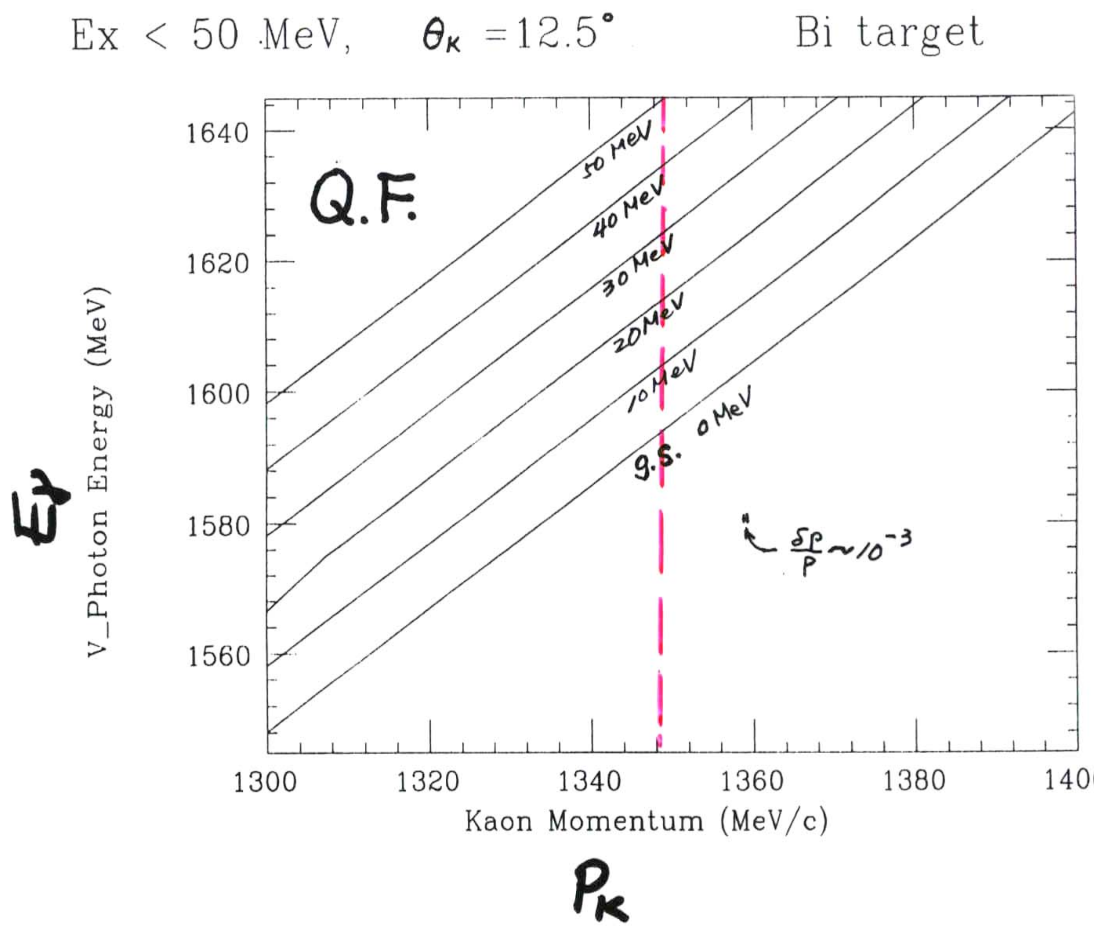
Expected Singles, Accidentals and KID Background

- SOS
  - Kaons: ~ 1/sec
  - Protons: ~ 50/sec
  - Pions: ~ 500/sec
- FF detector: ≤ 100K/sec
- (K,FF) coincidence: ~ 0.005/sec
- (K,FF) Accidentals: ~ 0.0002/sec
- S/A: ~ 25
- Prompt by Acc.: ~ 4%
- Prompt by KID backgrounds: ≤ 5%

Tag on Hypernuclear Production by Kaon Momentum Selection

- Assumed beam energy
  1.645 GeV

- Gate to the bound region to avoid contamination from free $\Lambda \to \pi N$ decay followed by π absorption



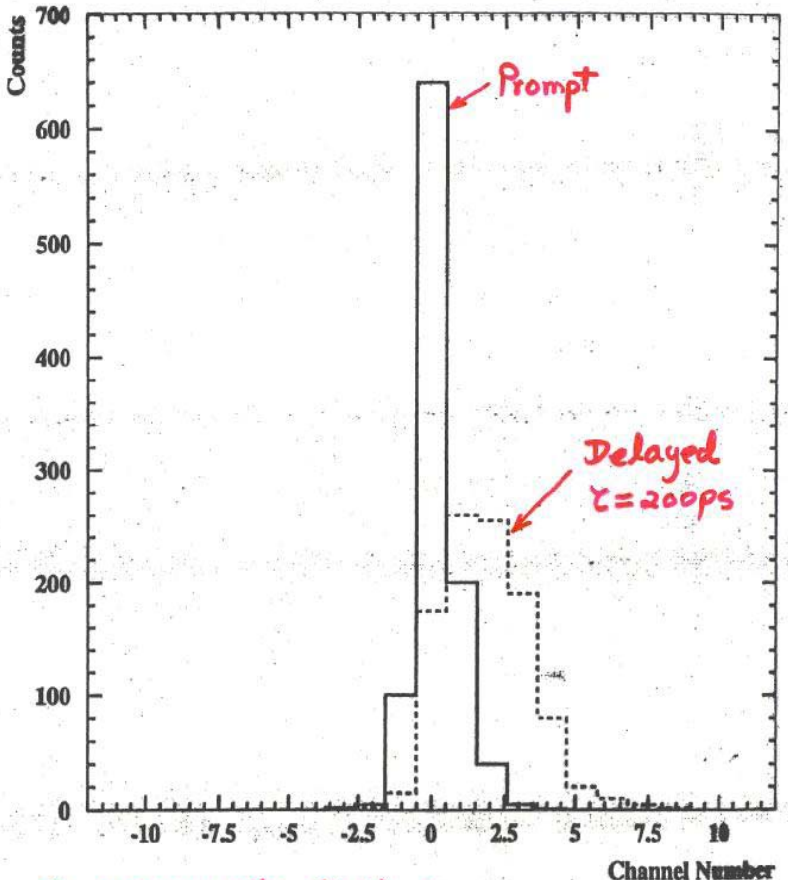
Time Components and Lifetime Fit

- If gated to the bound region, the decay time spectrum contains:
  - Delayed (>90%)
  - Prompt (can be studied precisely)
- Fit by 3 variables: N_p, N_t and τ

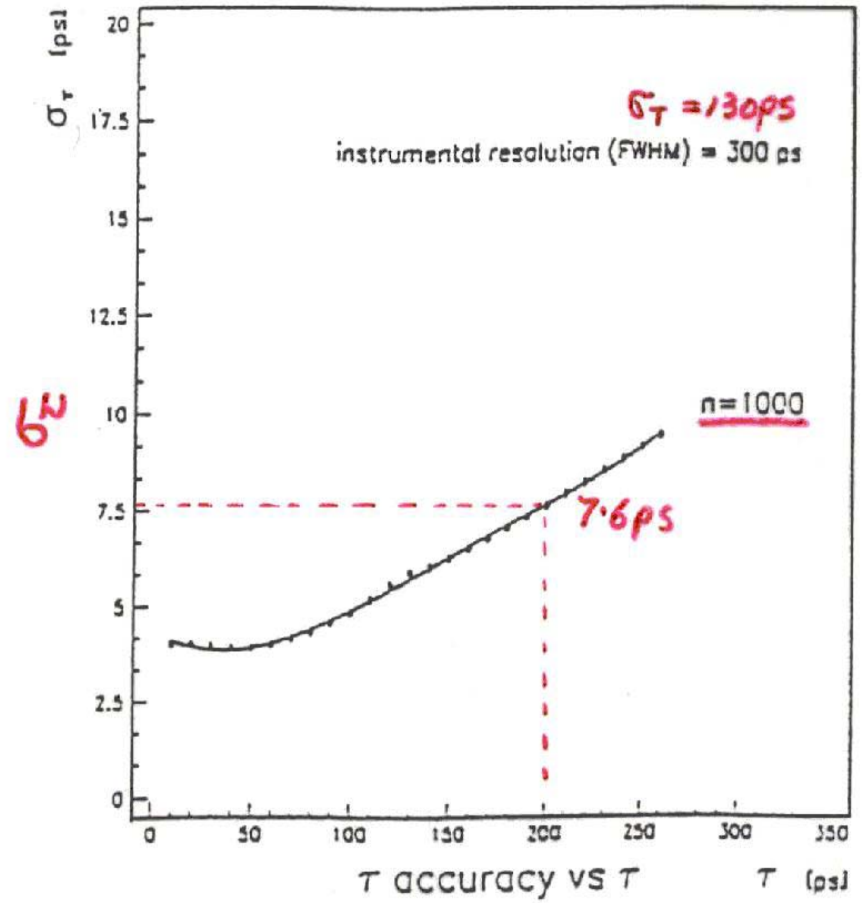
$$N_p * F_p(t) + N_t * \int F_p(\tau - t) F(\tau) dt$$

- Systematic errors:
  - Time zero (1.67ps or <1%)
  - Prompt $F_p(t)$ (<5ps or <2.5% if 1000 events)
- Dominated by statistical error from delayed t spectrum

Fit Accuracy (Statistical Error)



★ 1000 events (1:1)
★ σ_{total} = 110ps
} ⇒ $\delta\tau = \pm$ 7ps



Beam Requirement

- Beam energy: 1.8 – 2.0 GeV (CW)
- Beam current: 10-20 μA
- Data collection time: 7 days
- System commissioning: 3 days
- Estimated setup time: 7-10 days
  - Remove Hall C target
  - Setup LPMWPC

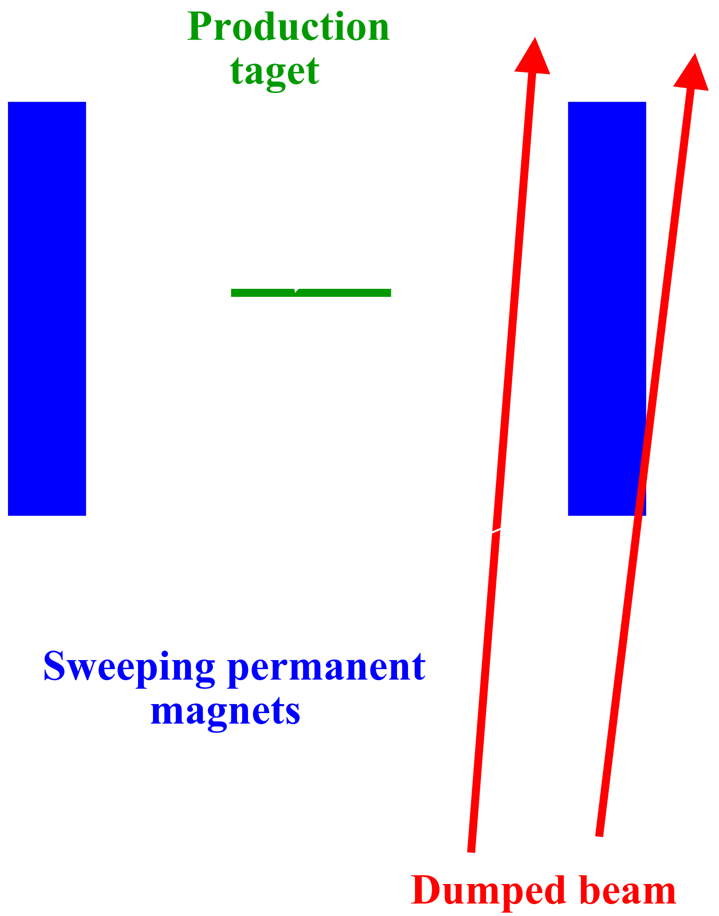
Status of LPMWPC Development

- Built and well tested by CF252 source in 1999
- Test results show achievement of the required time and position resolutions

  ($\sigma_t \sim$ 120 ps and $\sigma_x \sim$ 150 mm)
- Beam test was done in 2000, parasitically using dumped electron beam during the HNSS commissioning

Status of LPMWPC Development (Cont.)

- Miss tuned beam hitted the sweeping magnet with 1kW power
- Effective luminosity was much higher than actual experiment
- Clean fission signals were received, same as CF252 test
- No charge pile up effect was seen, i.e. sweeping magnets work well in sweeping low energy electrons
- Worked more than 24 hours before the wrapping aluminum foil melted



Status of LPMWPC Development (Cont.)

- LPMWPC was completely repaired and retested by CF252
- The performance characters restored
- It is ready for experiment
- We are confident that it will work under the experiment condition

Summary

- This experiment can measure the τ_L of heavy hypernuclei (A=208) directly with unprecedented precision and provide crucial A dependent test which is related to Γ_n/Γ_p ratio
- Hypernuclear production is positively tagged
- The experiment provides a feasibility test for the future experiment which detects two correlated α's from ^{8}Be after nonmesonic decay of the $^{10}{}_{\Lambda}$Be hypernuclei. It aims to measure Γ_n unambiguously with precision $\leq$10% as theory needed